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CANADIAN PATENT

LINER EXPANDER

Joe C. Stall, Tulsa, Oklahoma, U.S.A.

Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the vall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 35 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 45, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 13.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_{c} is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble \$1 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which 1 2 device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to 5 contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member 6 from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against 9 said liner-forming member, whereby said liner-forming member is urged against 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 3 conduit to expand said liner: a cylindrical shaft element, an expanding die h member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to 5 6 contact said liner, a cone member slidably positioned on said shaft between 7 said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
- 1 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing 2 3 plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact 6 with said come member, stop means connected to said shaft to limit the axial 7 travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

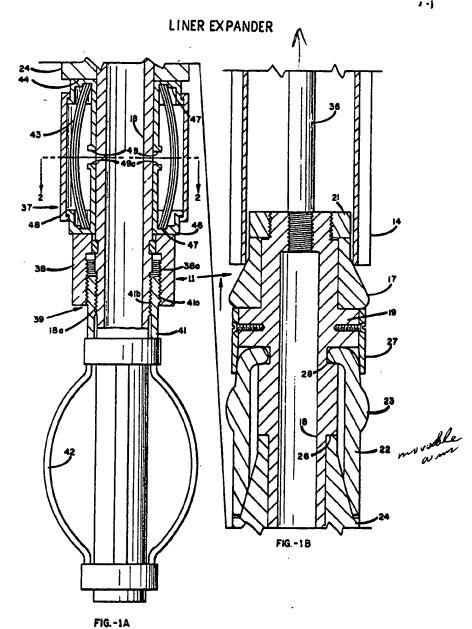
- 4. The device of Claim 3 wherein said compression means comprises
 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

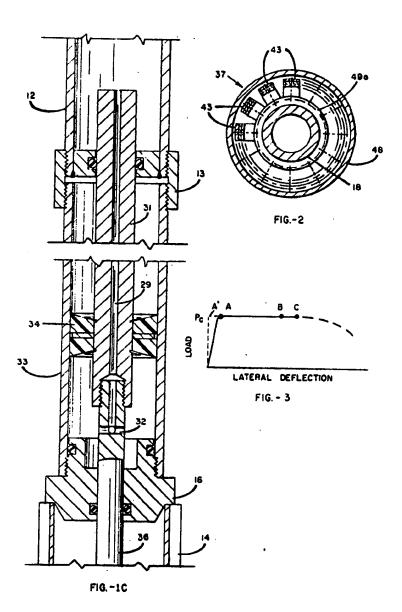
 sleeve-like element connected to said movable bearing plate member and

 slidably positioned on said shaft and a member connected to said shaft to

 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable out-5 wardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each 7 8 having a long rectangular cross-section and disposed circumferentially about 9 said shaft; an upper bearing plate member and a lower bearing plate member, 10 each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members 11 12 and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply 13 14 a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the 15 16 axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members 17 18 outwardly with a substantially constant force.

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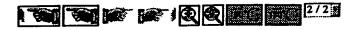
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A. A device for expending a metallic line; inside a conduct which device comprises a minit almost, an anymoting the member observed as mostle liner-forming member positioned on said shaft and being cartally novelle in respect theoret to contact and liner, as expender member aliably positioned on said shaft between said shaft and being cartally novel liner-forming member from said shaft and sould die member to move said liner-forming member from said shaft, said a constant force spring number positioned on said sport to contact said expender symbor had to maintain said expender member against the contact said suppose against said liner-forming symbor, whereby said liner-forming symbor is wrood against said liner by a substitutially constant force.

2. In a device few installing an expended astallic liner in a constate wherein an expending die is moved through a liner positioned in said somethy to support said liner; a cylindrical staff almost, an expending die member attached to said shart, and die member comprising a plurality of any numbers disposed around said shart and being physically metally therefore to contact still liner, a some number saidably positioned on said shart between said shart and said are members to topp said are senter as others for said any members to topp said are senter at the said to contact still cone number in contact with still are numbers, wherein said some numbers are urged outpartly by a substantially constant force.

3. The device of Claim & wherein said constant force spring newtorn congrises a plannity of column disposed scenes enid shift, a first tearing plate number and a second bearing plate scenes, each of said bearing plate members contacting opposite ents of said columns, at least one of said tearing plate numbers being movehly positioned on said shaft and being in contact white said come number, stop means commerted to said staff to limit the axial traveal of said moveble bearing plate number along said staff, and compression means for maintaining a letteral deflortion in said columns.





- . A, the device of Claim 3 wherehe ends compression group comprises a differential source ends sould shall.
- 5. The device of Claim 3 wherein said shop means comprises a alcove-like element commerced to said worship bearing plate combar and strainly positioned on said shaft and a souther commuted to said shaft to like the around of said alcove-like alcover.
- 6. The device of their 3 whereis said column have a maximization cross-section, the width being greater than the Wildmann, and bening the wider flow sevent to the diseases of said shaft.
- 7. A device for installing at expended untallin liner in a cominti ciers a criticarical shaft classical to accomplian the sector mental description are to tribute a principle a place values of the climber reminally around the embedde of each shaft and being plantable cetearthy therefrom to contact the liner; a stated expending states slidely hims agree of economic arm him both stade hims countries thode hims so be te outstantly from said shall; a planelity of elemen column, each beeing a long restingular consessestion and disposed einsustamentially shout suid chaft; an upper bearing plate maker and a lower tearing plate scatter, such shidship positioned on said shart and contacting opposite onto of said my limiting alsows ubleshed to such of stift bearing plats members and allifably positioned as said staft; a shoulder number on said shaft; a mainly secure almost commercing with shoulder and said shot's to apply sting look to stil enhance will shoulder being emphasize with the limiting micero summerted to each laster bearing plate mester, whereby the arial trevel of east bearing plate members is limited; east column vaccions branesitting their buckling look to onld arm numbers to urgs said arm grabers enteredly with a substantially comstant force.



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My invention will be better enterstood by returnes to the following description and the menumpassing drawings wherein:

Figure 14, 18 and 10, taken together, constitute a partial seetional view of a preferred subdiment of a liner expending tool assuming to the record description and

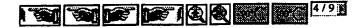




Figure 2 to a sestional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied lock versus believiton for the constant force spring device of the invention.

Referring to the drawings, Figure 12 is the letters portion of a liner expending took for one in installing a motable liner in a well, while Figure 15 silpertrates the middle section of such a tool and Figure 30 sepreseats the upper services of the tool. The expending tool 11 is abtembed to standers well taking 15 by ampling 15 and, typically, may be inverse from the murison through a well ensing (not shown) to a point in the surjug at which it to desired to invisit a metallic liner. Defer inscribe the test into the well, an elongsted varifically corregated liner 15 febricated from mild steel, or other suitable emilentic meterial, is placed on the tool. The corrugated liner is occured in position by contact at its upper end with a cylindrical ther 16 and, et the lower and by contact with a first-stage expansiing dis 17 in the form of a trumosted circular core which serves as a firstfixedly obtained to a controlly located, elemented epidedrical bollow shaft lô red a parties of the body of the tool. As shown, the expending file 17 is half in place between a lower shoulder 19 mod coller 21 threaded outo the . A plurality or soreble arms 29, precerably provided with outserdly salarged portions 25 mass the top, wie disposed in the form of a splindar al chaft 16. The calazged portions of the sens 25 upon being m liner into a substantially syllactical shaps. The are confers HE tre pirotally etteched to the sheft so as to be movehic outwardly from the sheft by a tapered mber 26 slikebly postificed on the sheft to corve as a se e. The sections of the master is, as shown, wower specially along the shall to sugage with the area and move them outvertily. Advantageously, the form sating sestions, typically outogonal is shope. The expension of the era are is controlled by the position of the member 24 raich moves appearelly



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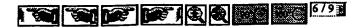






forces between the tool and the liner and the preserve exerted detiret the enting are maintained at presentational safe levels. The constant force spring manhor essures that the emphasis preserve between the liner forming portion 20 of the errs 22 is great enough to previde the desired deformation of the statement of the statem

The equators force spring seasor 7 is alidebly nomical on the shart 10 and hald between the expending alongst \$6 and a cylindrical inver chemidal master 10 forcing a portion of a differential server alonest 59 which transmits into looking on spring number 37 to chart mesher 18. The differential server alonest comprises shart unster 18 on the certain of units are sub-rate threads 18st, the lower chemider number 18 provided with framed threads 58 and thinkle number \$1 provided with threads with seal of the shallow and the incider, respectively, to employ with threads and the shart and the shallow are source, such as square, molified equare, or force threads are number, such as square, molified equare, or force threads, to vitherand very high loads and differ in pitch so that shoulder 38 is moved appearing on the shart 18 when the chart is revolved relative to thinkle \$1. The obsolider 38 is secured to the shart 18 by splines 53 so that it can alide immitability, but it is not tree to rotate on the chart. Finally arrached to the lower and of the thinkle is a friction number, such as but aprings \$2, a hydraulically equated friction pass, or other such devine for frictionally engaging with the inside wall of the cardwit to occurs the thinkle against trotation with respect to the obset. Fraturally, the direction of the shoulder number threads 38, with the pitch, or load, or threads 18a is slightly greater than these of threads 38, with the pitch rotate thing alone to unity. In this summer, clock-view revolution of the short relative to the thinkle summer shoulder search 38 to advance upwert alightly and a congression load is emerted upwardly on apring alament 37 to unsee builting. For wateria, one vertice accurate threads inch approximately 1.7-inch outside dismeter and tive and threads incide threads as a chart approximately 1.7-inch outside dismeter and tive and threads incide threads.

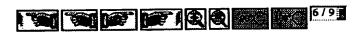


Donatest force spring element II comprises unions element 49, etractageomaly constitute or a phrelity of alongsied column disposed around shaft 15. Upper bearing plate content is in content with the apper ands of the animum and is aliabily positioned so shaft if to tracount the force of the agring longitudinally against the bottom and of expendes sendor sh. Lower bearing plate number 16 contents the lower ands of the columns and 10 moved spring plate sands by leadibulinal necessary of lossy shoulder 30 or a result of revolving differential sover almost 39. Greaves 17 are provided in send of the bearing plates, to form on open case and a lower sace, into which the case of the column are inserted. These grooves may be chaped to content with the chape of the column onto 17 secures. A cover 16 may be employed to anolade furnism uniter from the spring mechanism and to protect

A means for limiting the deflection of the columns to required. est functions in a bankled consistent, application of . properlys compressive load thereto would seems total failure or reptare of the refere, a pair of stope 69 and 150 are provided for this purpose. m, the stope are rigidly connected he the bearing plates, and, in effort comprise upper and lower limiting alarms positioned on the shaft to alide longitudinally thereon. The ends of the stope may nown toward, or enaach other as the look in the spring names vertes. Lever slaves \$9a. from sociled down by laster shoulder 35 someoted to the chart 18. on the ends in much so to limit the longitudinal travel of the bearing plate mesters on they more together to prevent perm deformation of the column almost \$3. Various alternative means for preventing seeage to the column element may also be employed. For example, year or rings someted on the obest may serve as atops, or the owner 48 provides with suitable connectance may be amployed for this purpose to limit longitudinal and/or lateral seflection of coinses.

The columns of the column classes of may be arranged exceed the chart lot, which as shown here there a portion of the body of the spring derive, with make of the columns fitted in the rease by. The columns may be

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ritied closely beginner as shows, we may be spaced around the race, with separators used between them to meistain the desired spacing. The number of solimes ampliqued will depond upon column characteristics and the materials of construction. For example, the standarders ratio of the column may be writed widely, sad the column units may be round, flat, flund or hinged. The preferred construction is a thin, element column with receded ands, from to now within the races shaped to the convenient of the column sade. Materials which may be astisfectorily employed for the column are on them and has allow steads, chronius and minimal-shronius stainless steels, vertices appear becomes, beryline separate, restained providing artisfectory mechanical properties. Typically, the indiminatorial solumns are or long rectamples cross-certion, with the stath bring greater than the likichness, and arranged so that the wider face of the unimage is normal to the simulator of the about. Thus, with surfacient construction insiding, the columns buckle, and tood about the sain having the loast consent of inartia, e.g., outwartly may from the about 18.

For example, a group of columns 0.167-inch thick by 0.435-inch tific by 10.636-inches long, with the ends rousead, were febrioated from i.f.6.I 4340 steel, quenched and draws at 775°7. But column was found to require a critical congression losding or 550 pounds in order to buckle the calumn.

After bunkling, the columns were found to have a very first spring characteristic, as shows in Figure 3, wherein Police the critical bunkling lead and points 0 represents the load and deflection at which the stress in the extense fibers of this spring ubaracteristic curve is described by core Cd'A30. Actually, the chape of this spring ubaracteristic curve is described by core Cd'A30. Actually, this captures typical sorting limits, which, of course, may be varied sententing to the application for which the spring is designed. For example, where a large number of flexing spulse are not multiplied, a working atrace just below the stress may be held to less than the enforces limit of the material of scorters time. In the above-manticed tests, the lateral intraction was limited to





approximately one fuch, at which the longitudinal deflortion was approximately 0.225 inches. From earn deflortion to the assume deflortion, the \$50-pound loading was found to be substantially constant.

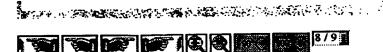
In another test a spring durine was built, as deem, employing 80 columns, each having a critical bushing load of 1850 posses. The internal definition was limited between 0 and about 1.00 inches by empropriately positioning the stope. Once compressional loading, the spring element buckled at emetantially 25,000 posses and from a longitudinal defication of 0.05 inches (making) to stook 0.15 inches the lead remained substantially at 25,000 posses.

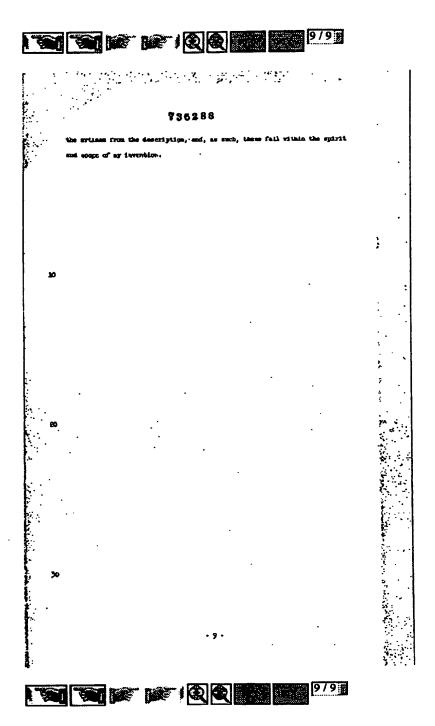
Of course, in douigning a spring elevant as above it is advantageous to obtain the greatest possible value of longitudinal defination for specifical values of lateral deflection and critical bushing load, while unintering the stress level in the columns at a cafe level. The preferred columns, therefore, are laminated, as shown in Figures 13 and 2, with unitiple flat analysis and a call of the columns and a call of the columns and a call of the columns.

In the operation of the shows capteling tool for setting a liner in well section, the made-up tool is lowered into the sell as sectioned above, with the area 22 is the retreated position. Then the tool is at the Seniral level, the well taking is retained. The friction member his capages with the wall of the mating and prevents thinkle hi from revolving. With several revolutions of the taking, knear shoulder 35 is nowed measurily by differential nerve 39 to bushle oping almost 37 which has a predefermined critical buckling level. This level is transmitted squarely against the lower cal of expender 25, and the tapered surface is engaged with the tapered surface on the lattice of the own 22 to urgs the turn cutturily with a substantially constant ferce proportional to the critical bushling load of the syring almost. Subsequently, the expending tool is passed through the lines to expend 15 in the caping in the senser described by each over.

The foregoing teneription of a preferred established of an investigation has been given for the purpose of examplification. It will be understood that various mathifications in the details of empirication will become apparent to

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